Novel Heavy Flavor Suppression Mechanisms in the Quark-gluon Plasma

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Quantum chromodynamics, the fundamental theory of strong interactions, predicts that at exceedingly high temperatures and densities ordinary nuclear matter should melt down in a plasma-like state of quarks and gluons. One of the important experimental signatures of the quark-gluon plasma (QGP) creation in heavy ion collisions is the detailed suppression pattern of high transverse momentum (p_T) hadrons, dubbed jet quenching [1]. Jet quenching for light mesons, such as π, K, and η, at the Relativistic Heavy Ion Collider (RHIC) is well explained by radiative energy loss calculations. One such example of neutral pion suppression in Au+Au and Cu+Cu reactions is shown in Fig.1. Our theoretical calculations of the QGP-induced suppression R_{AA} versus p_T and the colliding system size show good agreement with the PHENIX experimental data.

In contrast, recent data on the suppression of single non-photonic electrons, coming from the decay of heavy charm (D) and beauty (B) mesons, cannot be reproduced by medium-induced gluon bremsstrahlung phenomenology in conjunction with a physically reasonable set of QGP temperatures and densities. Recently, we identified a possible reason for this striking discrepancy [2]. The model for predicting the quenched hadron spectra in A+A collisions, where final-state-in-medium effects are important, has been very simple: it is assumed that the hard jet hadronizes in vacuum, having fully traversed the region of dense nuclear matter, $L^T_{QGP} \sim 6$ fm. It is easily demonstrated that this assumption is not valid for the heavy charm and beauty quarks and mesons. In fact, for p_T = 10 GeV they tend to form at times t = 0.4 fm and t = 1.5 fm, respectively, well within the hot and dense QGP phase. Consequently, the natural mechanism of heavy flavor suppression is a competition between D- and B-meson dissociation and c- and b-quark fragmentation, both of which emulate energy loss. Our predictions for the suppression $R_{AA}(p_T)$ of e^++e- coming from the semi-leptonic heavy flavor decays are compared in Fig. 2 with the STAR and PHENIX data [3]. Thus, our approach presents an elegant resolution to the "heavy flavor puzzle" at RHIC.

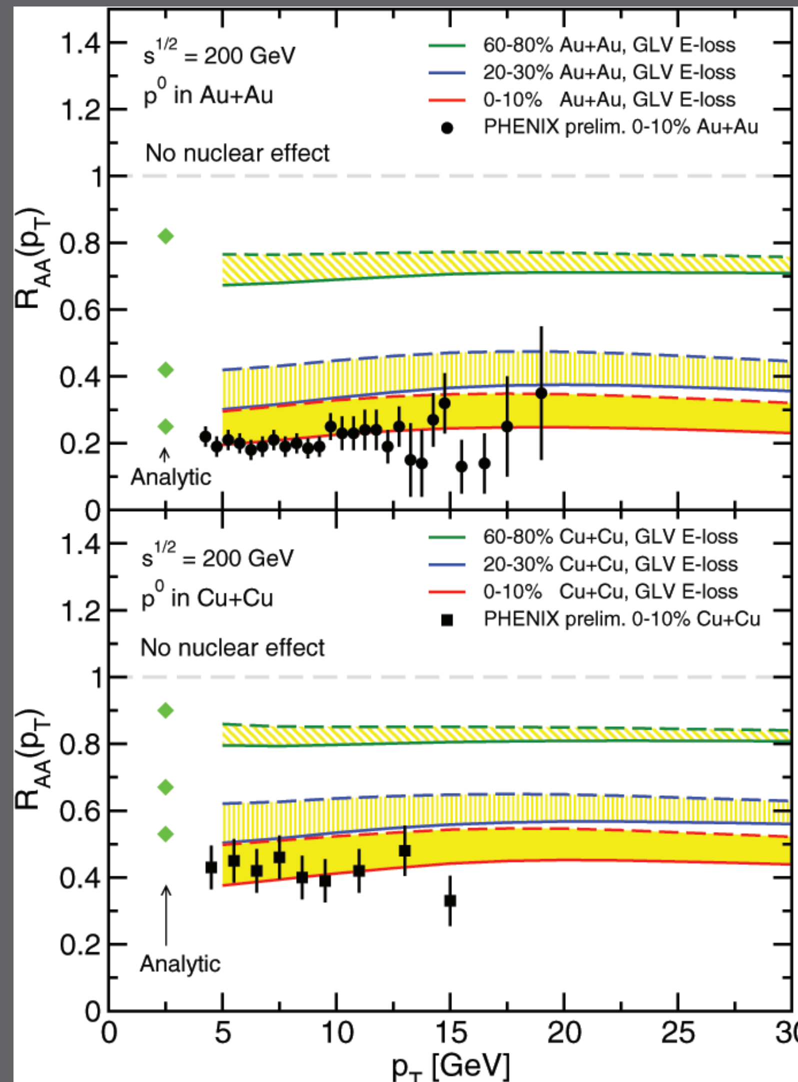

Fig. 1. Top panel: neutral pion quenching predictions versus p_T and centrality in Au+Au collisions at RHIC compared with the PHENIX central suppression data at C.M. energy of 200 GeV. Bottom panel: similar comparison is done in Cu+Cu reactions.

A natural *unique* consequence [4] of this theory is that B-mesons are attenuated as much as D-mesons at transverse momenta as low as $p_T \sim 10$ GeV for the conditions prevalent in central Au+Au collisions at C.M. energy of 200 GeV (Fig. 3). Our model will be put to a critical test by experimental advances aiming at direct and separate measurements of D- and B-meson $R_{AA}(p_T)$ [5].

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Funding Acknowledgments
- Department of Energy, Office of Science
- J. Robert Oppenheimer Fellowship
- Los Alamos National Laboratory Directed Research and Development Program

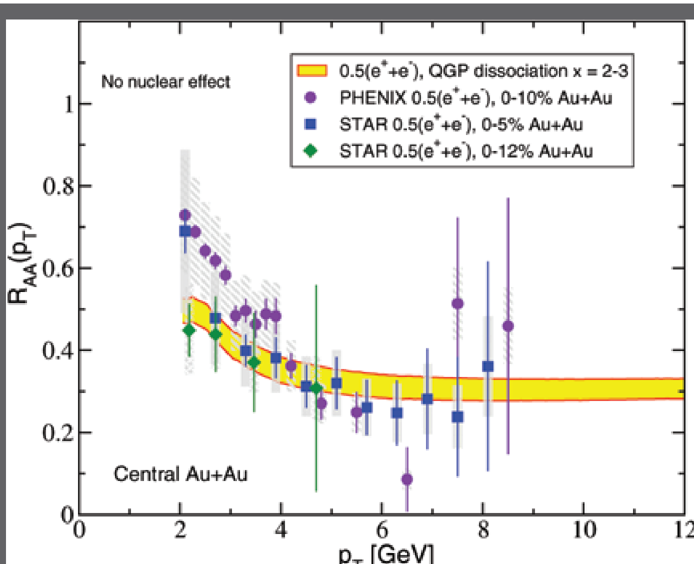

Fig. 2. Suppression of inclusive non-photonic electrons from D- and B-meson spectra softened by collisional dissociation in central Au+Au collisions. Data on non-photonic electron quenching is from PHENIX and STAR.

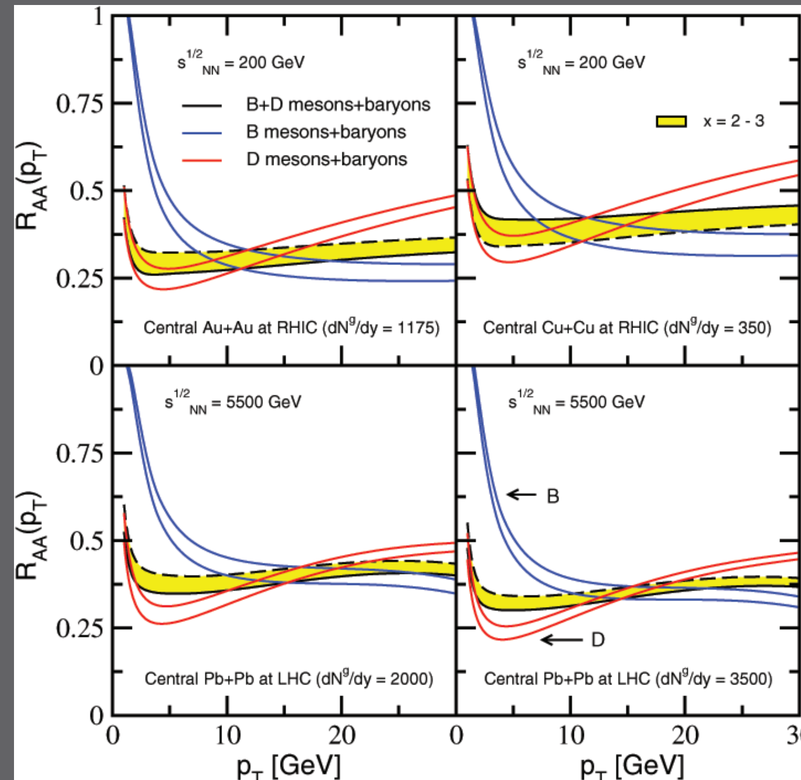

Fig. 3. Individual suppression of D- and B-meson production via collisional dissociation in the QGP. Top panels show numerical results for $R_{AA}(p_T)$ in central Au+Au and Cu+Cu collisions at RHIC. Bottom panel shows predictions for central Pb+Pb collisions at the LHC.